Astronomy(Annual Report(from April 2000 to March 2001))

Astronomy

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Research Activities

(I) Stars

1. *The evolution of a rapidly accreting helium white dwarf to become a low-luminosity helium star* (H. Saio and C.S. Jeffery)

We have examined the evolution of merged low-mass double white dwarfs which become low-luminosity (or high-gravity) extreme helium stars. These models have properties very

similar to those of the pulsating helium star V652 Her. We have compared the rate of period change of the theoretical models with that observed in V652 Her, as well as with its position on the HR diagram.

2. *Nonradial pulsations in Epsilon Persei* (H. Saio, E. Kambe, and U. Lee)

We consider the question of whether all the modes detected in the line profile variations of epsilon Persei are consistent with nonradial pulsations excited by the kappa mechanism at the Z-bump. We have examined the effect of rotation on the stabilityand found that the stabilizing effect is weak. No significant difference is found between prograde and retrograde modes in the stability.

Publications

1. The evolution of a rapidly accreting helium white dwarf to become a low-luminosity helium star, H. Saio and C.S. Jeffery, 2000, Mon. Not. R. Astron. Soc. 313, 671-677
2. Nonradial Pulsations in epsilon Persei, H. Saio, E. Kambe, and U. Lee, 2000, ApJ. 543, 359-367

(II) Compact Stars, Black Holes, and Related Phenomena

1. *Radiation Spectra from ADAF in a Global Magnetic Field* (M. Kino, O. Kaburaki and N. Yamazaki)

Broadband spectra of advection-dominated accretion flows (ADAFs) in a global magnetic field are calculated, based on the alalytic model of Kaburaki in which a large-scale magnetic field controls the accretion process. Adjusting a few parameters, we find that our model well reproduce the observed spectrum of Sgr A*. The results are also discussed in comparison with those of the well-known, viscous ADAF models.

2. *Inertial modes of slowly rotating isentropic stars* (YOSHIDA, Sijun and LEE, Umin)

In this paper, we examine the secular stability of r-modes and inertial modes of isentropic stars, where the stability is determined by the balance between gravitational wave radiation reaction (destabilization) and viscous processes (stabilization) possible in young hot neutron stars. We found that the fundamental r-mode assoicated with $l = m = 2$ is the most unstable one. Inertial modes can be unstable due to the gravitational radiation, but the strength of the instability is much weaker than that of the r-mode .

3. *Equation of Motion for Relativistic Compact Binaries with the Strong Field Point Particle Limit: Formulation, the First Post-Newtonian, and Multipole Terms* (Yousuke Itoh, Toshifumi Futamase, and Hideki Asada)

We rederive an equation of motion applicable to inspiralling relativistic compact binary star systems accurate through the first post-Newtonian order. The spin-orbit and quadrupole-orbit coupling force are also derived. To derive the equation, we employ a

surface integral approach and the strong field point particle limit, which enable us to deal with compact stars.

4. *Equation of Motion for Relativistic Compact Binaries with the Strong Field Point Particle Limit: the Second and Half Post-Newtonian Order* (Yousuke Itoh, Toshifumi Futamase, and Hideki Asada)

The equation of motion for two body problem in general relativity are derived accurate through the second and half post -Newtonian order. The key features of our method, the strong field point particle limit and the surface integral approach, ensure the applicability of our resulting equation to relativistic compact binary star systems.

5. *A numerical study of the r-mode instability of rapidly rotating nascent neutron stars* (Shin'ichirou Yoshida, Shigeyuki Karino, Shijun Yoshida and Yoshiharu Eriguchi)

The first results of numerical analysis of classical r-modes of rapidly rotating compressible stellar models are reported. We find that rotational frequencies of 1.4 solar mass stars suffering from r-mode instability decrease to around 100 Hz when the standard cooling mechanism of neutron stars is employed. This results confirms the results of other authors, who adopted the slow rotation approximation.

6. *Rotational modes of non-isentropic stars and the gravitational radiation driven instability* (Shijun Yoshida and Umin Lee)

We investigate the properties of rotational modes of slowly rotating, non-isentropic, Newtonian stars, by taking account of the effects of the Coriolis force and the centrifugal force. It is found that the gravitational radiation driven instability of the fundamental r-modes associated with $l' = |m|$ remains strong even in the non-isentropic models.

7. *r-mode oscillations of rapidly rotating Newtonian stars : A new numerical scheme and its application to the spin evolution of neutron stars* (Shigeyuki Karino, Shin'ichirou Yoshida, Shijun Yoshida and Yoshiharu Eriguchi)

We developed a new numerical scheme to solve r-mode oscillations of rapidly rotating polytropic stars in Newtonian gravity. By using this scheme, we solved the classical r-mode oscillations of rotational equilibrium sequences of ploytropes. From obtained results, we have found that maximum angular velocities of neutron stars are around 10–20 % of the Keplerian limit.

8. *r-modes of neutron stars with a solid crust* (Shijun Yoshida and Umin Lee)

We investigate the properties of r-mode oscillations of a slowly rotating neutron star with a solid crust, by taking account of the effects of the Coriolis force. It is found that the core r-modes are strongly affected by mode coupling with the crustal torsional modes and lose their simple properties of the eigenfunction and eigenfrequency as functions of the angular rotation velocity Ω.

Publications

1. Radiation Spectra from Advection-Dominated Accretion Flows in a Global Magnetic

Field, M. Kino, O. Kaburaki and Y. Yamazaki, 2000, ApJ, 536, 788-797.
2. Inertial modes of slowly rotating isentropic stars, Yoshida, S., and Lee, U., ApJ **529** (2000), 997-1010.
3. Equation of Motion for Relativistic Compact Binaries with the Strong Field Point Particle Limit: Formulation, the First Post-Newtonian, and Multipole Terms, Yousuke Itoh, Toshifumi Futamase, and Hideki Asada, Phys. Rev. D**62** (2000), 064002
4. Equation of Motion for Relativistic Compact Binaries with the Strong Field Point Particle Limit: the Second and Half Post-Newtonian Order, Yousuke Itoh, Toshifumi Futamase, and Hideki Asada, Phys. Rev. D**63** (2001), 064038
5. A numerical study of the r-mode instability of rapidly rotating nascent neutron stars, 2000, Mon. Not. R. Astron. Soc., 316, L1-L4, Shin'ichirou Yoshida, Shigeyuki Karino, Shijun Yoshida, Yoshiharu Eriguchi
6. Rotational modes of non-isentropic stars and the gravitational radiation driven instability, 2000, ApJ Suppl., 129, 353-366, Shijun Yoshida, Umin Lee
7. r-mode oscillations of rapidly rotating Newtonian stars : A new numerical scheme and its application to the spin evolution of neutron stars, 2000, Phys. Rev. D, 62, 084012-1–084012-11, Shigeyuki Karino, Shin'ichirou Yoshida, Shijun Yoshida, Yoshiharu Eriguchi
8. r-modes of neutron stars with a solid crust, 2001, ApJ, 546, 1121-1125, Shijun Yoshida, Umin Lee

(III) Interstellar Matter

1. *Nova V4444 Sagittari 1999: Spectropolarimetric Evidence for a Preexistng Circumstellar Dust Cloud* (K. Kawabata, R. Hirata, Y. Ikeda, H. Akitaya, M. Seki, M. Matsumura and A. Okazaki)

We carried out low dispersion spectropolarimetry for a very fast nova V4444 Sgr 1999 in its earliest stage (t = 2-10 days) over a wide range at optical wavelength region. By careful decomposition of intrinsic component from the observed polarization, we obtained clear evidence for preexistence of a dust cloud in the vicinity of the nova at least several dozens of AU from the central star. Its origin and properties are discussed.

2. *High-Resolution Images of the Ring Nebula Taken with the Subaru Telescope.* (Y. Komiyama, M. Yagi, S. Miyazaki, S. Okamura, S. Tamura, H. Fukushima, and Suprime-Cam team)

The authors present high-resolution images of the Ring Nebula in the H_α, V, and B bands taken with the Subaru telescope. The H_α image reveals the fine structure of the inner and outer halos in unprecedented detail. The innermost part of the inner halo just outside of the main ring may be identified as a new component in terms of the surface brightness hierarchy seen in the Ring Nebula. The outer halo is found to show a limb-brightened knotty structure similar to the inner halo, but at much fainter levels.

Publications

1. Nova V4444 Sagittari 1999: Spectropolarimetric Evidence for a Preexistng Circumstellar Dust, 2000, K.Kawabata, R. Hirata, Y. Ikeda, H. Akitaya, M. Seki, M.Matsumura and A. Okazaki, Astrophys. J. 540 429-435(2000).
2. High-Resolution Images of the Ring Nebula Taken with the Subaru Telescope, Y. Komiyama, M. Yagi, S. Miyazaki, S. Okamura, S. Tamura, H. Fukushima, and Suprime-Cam team, 2000, Publ. Astr. Soc. Japan, **52**, 93-98 and Plate 20-22.

(IV) Galaxies : Theory

1. *Effects of dust extinction of optical spectroscopic properties for starburst galaxies in distant clusters* (Yasuhiro Shioya, Kenji Bekki)

We numerically investigate spectroscopic and photometric evolution of dusty starburst galaxies. We found that if a young starburst population is preferentially obscured by dust than an old one in a dusty starburst galaxy, the galaxy shows e(a) spectrum that is characterized by strong Hδ absorption and relatively modest [OII] emission.

2. *On the degree of dust extinction in major galaxy mergers with dusty starburst* (Kenji Bekki, Yasuhiro Shioya)

We found that an infrared luminous galaxy with dusty starburst formed by a nearly retrograde-retrograde merger suffers the most remarkable dust extinction of stellar light and consequently shows very red colors. We also found that a retrograde-retrograde merger does not produce strong and long tidal tails.

3. *Formation and evolution of dusty starburst galaxies. I. A new method for deriving spectral energy distribution* (Kenji Bekki, Yasuhiro Shioya)

We present a new numerical code which is designed to derive a spectral energy distribution (SED) for an arbitrary spatial distribution of stellar and gaseous components in a dusty starburst galaxy. By using this code, we can investigate simultaneously dynamical and photometric evolution of a dusty galaxy based on stellar and gaseous dynamical simulations.

4. *LMSA and high-redshift dusty starburst mergers* (Kenji Bekki, Yasuhiro Shioya)

We have investigated the time evolution of morphological properties, the star formation rate, and the submillimeter flux at 850 μm in high-redshift dusty starburst mergers with mass ratio (m_2) of two disks ranging from 0.1 to 1.0. We found that the maximum star-formation rate, the degree of dust extinction, and the 850 μm flux are larger for mergers with larger m_2.

5. *Formation and evolution of E+A galaxies in dusty starburst galaxies* (Kenji Bekki, Yasuhiro Shioya, Warrick J. Couch)

We model the spectral, dynamical and morphological evolution of a dusty starburst associated with a major galaxy merger. We show that as this system evolves dynamically, its spectral type changes from an "e(a)" type to a k+a type and then finally to a passive "k" type.

Publications

1. Effects of dust extinction of optical spectroscopic properties for starburst galaxies in distant clusters, Yasuhiro Shioya, Kenji Bekki, 2000, ApJ, 539, L29

2. On the degree of dust extinction in major galaxy mergers with dusty starburst, Kenji Bekki, Yasuhiro Shioya, 2000, A&A, 362, 97

3. Formation and evolution of dusty starburst galaxies. I. A new method for deriving spectral energy distribution, Kenji Bekki, Yasuhiro Shioya, 2000, ApJ, 542, 201

4. LMSA and high-redshift dusty starburst mergers, Kenji Bekki, Yasuhiro Shioya, 2001, PASJ, 52, L57

5. Formation and evolution of E+A galaxies in dusty starburst galaxies, Kenji Bekki, Yasuhiro Shioya, Warrick J. Couch, 2001, ApJ, 547, L1

(V) Galaxies: Observation

1. *Discovery of a Low Surface Brightness Object near Seyfert's Sexte* (T. Murayama, S. Nishiura, T. Nagao, Y. Sato, Y. Taniguchi, D.B. Sanders)

We report the discovery of a low surface brightness (LSB) object serendipitously found during deep CCD imaging of a compact group of galaxies, Seyfert's Sextet, in the VR and I bands. The LSB object is located 2 southwest from the group's center. The apparent magnitudes are mAB(VR)=19.87 and m(I)=19.06. The object is most likely an LSB dwarf galaxy, but other possibilities are also discussed.

2. *Detection of the VLBI-Scale Counter Jet in NGC 6251* (H. Sudou, Y. Taniguchi, Y. Ohyama, S. Kameno, S. Sawada-Satoh, M. Inoue, O. Kaburaki, & T. Sasao)

Mapping the central 5 pc region of the nearby radio galaxy NGC 6251 with a 0.2 pc resolution using VLBI at two radio frequencies, 5 GHz and 15 GHz, we have found the sub-pc-scale counter jet for the first time in this radio galaxy. This discovery allows us to investigate the jet acceleration based on the relativistic beaming model (Ghisellini et al. 1993).

3. *Grain Survival in Supernova Remnants and Herbig-Haro Object* (H. Mouri, & Y. Taniguchi)

The [Fe II]/[O I] flux ratio is sensitive to the gas-phase Fe/O abundance ratio but is insensitive to the ionization state, temperature, and density of the gas. By using the [Fe II]λ8617/[O I] λ 6300 flux ratio, we demonstrate that most of the interstellar dust grains survive in shocks associated with supernova remnants and Herbig-Haro objects. This finding is in conflict with the current consensus that shocks destroy almost all the grains and that 100

4. *High-Ionization Nuclear Emission-Line Region of Seyfert Galaxies* (T. Nagao, Y. Taniguchi, & T. Murayama)

In order to investigate viewing angles toward narrow-line Seyfert 1 galaxies (NLS1s) and intermediate types of Seyfert galaxies, we apply the HINER test to them. We also apply the same test for S2s with and without the hidden broad-line region. We find that the NLS1s are viewed more face-on toward dusty tori than the S2s. However, the HINER properties of the NLS1s are indistinguishable from those of the S1s.

5. *The Nuclear Activity of Galaxies in the Hickson Compact Groups* (M. Shimada, Y. Ohyama, S. Nishiura, T. Murayama, & Y. Taniguchi)

In order to investigate the nuclear activity of galaxies residing in compact groups of galaxies, we present results of our optical spectroscopic program made at Okayama Astrophysical Observatory. We have performed optical spectroscopy of 69 galaxies belonging to 31 Hickson compact groups (HCGs) of galaxies. We find that there is no statistically significant difference in the frequency of occurrence of emission-line galaxies between the HCGs and the field. This implies that the dense galaxy environment in the HCGs does not affect the triggering of either the AGN activity and the nuclear starburst.

6. *Formation of Intermediate-Mass Black Holes in Circumnuclear Regions of Galaxies* (Y. Taniguchi, Y. Shioya, T. G. Tsuru, & S. Ikeuchi)

Recent high-resolution X-ray imaging studies have discovered possible candidates of intermediate-mass black holes with masses of $M \approx 10^{2-4} M_{\odot}$ in circumnuclear regions of many (disk) galaxies. It is known that a large number of massive stars are formed in a circumnuclear giant H II region. Therefore, we propose that a continual merger of compact remnants left from these massive stars is responsible for the formation of such an intermediate-mass black hole within a timescale of 109 yr. A necessary condition is that several hundreds of massive stars are formed in a compact region with a radius of a few parsecs.

7. *Luminous Infrared Galaxies. III. Multiple Merger, Extended Massive Star Formation, Galactic Wind, and Nuclear Inflow in NGC 3256* (S.Lipari, R. Diaz, Y. Taniguchi, R. Terlevich, H. Dottori, G. Carranza)

We report detailed evidence for multiple merger, extended massive star formation, galactic wind, and circular/noncircular motions in the luminous infrared galaxy NGC 3256, based on observations of high-resolution imaging (Hubble Space Telescope, ESO NTT), and extensive spectroscopic data (more than 1000 spectra, collected at Estacion Astrofisica de Bosque Alegre, Complejo Astronomico el Leoncito, Cerro Tololo InterAmerican Observatory, and IUE observatories).

8. *Large-Scale Regular Morphological Patterns in the Radio Jet of NGC 6251* (H. Sudou, & Y. Taniguchi)

We report on large-scale regular morphological patterns found in the radio jet of the nearby radio galaxy NGC 6251. Investigating morphological properties of this radio jet from the nucleus to a radial distance of 300" (140 kpc) mapped at 1662 MHz and 4885 MHz by Perley, Bridle, Willis, in the first two chains consist of three small subknots

(the triple-knotty substructures). We discuss the observational properties of these regular morphological patterns.

9. *ISO deep far-infrared survey in the "Lockman Hole". II. Power spectrum analysis: evidence of a strong evolution in number counts* (H. Matsuhara, K. Kawara, Y. Sato, Y. Taniguchi, H. Okuda, T. Matsumoto, Y. Sofue, K. Wakamatsu, L. L.Cowie, R. D. Joseph, & D. B. Sanders)

We investigate the characteristics of FIR brightness fluctuations at 90 μm and 170 μm in the Lockman Hole, which were surveyed with ISOPHOT aboard the Infrared Space Observatory (ISO). We first calculated the angular correlation function of each field and then its Fourier transform (the angular Power Spectral Density: PSD) over the spatial frequency range of f=0.05-1 arcmin^{-1}. The PSDs are found to be rather flat at low spatial frequencies (f ¡= 0.1 arcmin-1), slowly decreasing toward higher frequencies. These spectra are unlike the power-law ones seen in the IR cirrus fluctuations, and are well explained by randomly distributed point sources.

10. *Poststarburst Models of LINERS* (Y. Taniguchi, Y. Shioya, & T. Murayama)

We present new poststarburst models that explain some of most important optical narrow emission line ratios of low-ionization nuclear emission-line regions (LINERs). In these models, the ionization sources are planetary nebula nuclei (PNNs) with temperature of $\sim 10^5$ K that appear in the late-phase evolution of intermediate-mass stars with mass between 3 and 6 $M_\odot$. Such PNNs left in a typical starburst nucleus can produce an Hα luminosity of $L(\mathrm{H}\alpha) \sim 10^{38}$ ergs s^{-1} for typical poststarburst LINERs.

11. *How do we see the nuclear region ($r < 0.1$ pc) of narrow-line Seyfert 1 galaxies?* (T. Murayama, T. Nagao, & Y. Taniguchi)

We propose two statistical tests to investigate how we see the nuclear region (r¡0.1 pc) of narrow-line Seyfert 1 galaxies (NLS1s): 1) The high-ionization nuclear emission-line region (HINER) test, and 2) The mid-infrared test. Applying these tests to a sample of NLS1s, we have found that the NLS1s possibly have nearly the same properties as S1s.

12. *A Dynamical Study of Galaxies in the Hickson Compact Groups* (S. Nishiura, M. Shimada, Y. Ohyama, T. Murayama, & Y. Taniguchi)

To investigate dynamical properties of spiral galaxies in the Hickson compact groups (HCGs), we present rotation curves of 30 galaxies in 20 HCGs. It is shown that the dynamical properties of HCG spiral galaxies do not strongly correlate with the morphology, the nuclear activity, and the group properties. Our results also suggest that more frequent galaxy collisions occur in the HCGs than in the field and in the clusters.

13. *X-Ray Emission from Seyfert 2 Galaxies with Optical Polarized Broad Lines* (H. Awaki, S. Ueno, K. A. Weaver, & Y. Taniguchi)

We analyze the 0.5-10 keV spectra of six Seyfert 2 galaxies observed with the X-ray satellite ASCA. We estimate a typical scattering efficiency for X-rays to be about 10This efficiency is larger than the few percent found for ordinary Seyfert 2 galaxies. Since the difference between our sample and ordinary Seyfert 2 galaxies can be explained by the

difference of viewing angle, the similar scattering efficiency suggests the existence of a scattering region that is larger than the putative dusty torus.

14. *Deep Optical Imaging of a Compact Group of Galaxies: Seyfert's Sextet* (S. Nishiura, T. Murayama, M. Shimada, Y. Sato, T. Nagao, K. Molikawa, Y. Taniguchi, & D. B. Sanders)

To investigate the dynamical status of Seyfert's Sextet (SS), we have obtained a deep optical (VR+I) image of this group. Our image shows that a faint envelope, down to a surface brightness μ(AB)=27 mag arcsec^{-2}, surrounds the member galaxies. This envelope is irregular in shape. It is likely that this shape is attributed either to recent-past or to ongoing galaxy interactions in SS.

15. *Dwarf Galaxy Formation Induced by Galaxy Interactions* (T. Okazaki, & Y. Taniguchi)

Recent observations suggest strongly that the formation of most dwarf galaxies is linked to galaxy interactions. Therefore, now seems like the right time to investigate the formation efficiency of such tidal dwarf galaxies. Adopting the galaxy interaction scenario proposed by Silk and Norman, we find that if only a few dwarf galaxies are formed in each galaxy collision, we are able to explain the observed morphology-density relations for both dwarf and giant galaxies in the field, groups of galaxies, and clusters of galaxies.

16. *Numerous Old Starburst Galaxies in the Local Universe* (H. Mouri, & Y. Taniguchi)

Old starburst galaxies are deficient in O stars and hence do not exhibit strong line emission in the optical regime. However, there remain many B stars, which are expected to heat dust grains and generate strong continuum emission in the far-infrared. The IRAS data for a statistically complete sample of nearby galaxies reveal for the first time that such objects are as numerous as 30% - 40% of the local galaxy population.

17. *Sub-Parsec-Scale Acceleration of the Radio Jet in the Powerful Radio Galaxy NGC 6251* (H. Sudou, Y. Taniguchi, Y. Ohyama, S. Kameno, S. Sawada-Satoh, M. Inoue, O. Kaburaki, & T. Sasao)

In order to investigate the genesis of a powerful radio jet, we have mapped the central 10 pc region of the nearby radio galaxy, NGC 6251, with a 0.2 pc resolution using Very Long Baseline Interferometer (VLBI) at two radio frequencies, 5 GHz and 15 GHz. We have found the sub-parsec-scale counterjet for the first time in this radio galaxy. This discovery allows us to investigate the jet acceleration based on the relativistic beaming model.

18. *ISO continuum observations of quasars at z=1-4. I. Spectral energy distributions of quasars from the UV to far-infrared* (S. Oyabu, K. Kawara, Y. Tsuzuki, Y. Sofue, Y. Sato, H. Okuda, Y. Taniguchi, H. Shibai, C. Gabriel, T. Hasegawa, & E. Nishihara)

Eight luminous quasars with $-30 < M_B < -27$ at $z = 1.4$-3.7 have been observed in the mid- and far-infrared using ISO. The SEDs are compared with the MED (Mean spectral Energy Distributions) of low-redshift quasars with $-27 < M_B < -22$. It is shown that our far-infrared observations were limited by confusion noise due to crowded sources.

19. *The Narrow-Line Region of Seyfert Galaxies: Narrow-Line Seyfert 1 Galaxies versus Broad-Line Seyfert 1 Galaxies* (T. Nagao, T. Murayama, & Y. Taniguchi)

In order to examine whether or not there are differences in the physical conditions of NLR

gas between narrow-line Seyfert 1 (NLS1's) and broad-line Seyfert 1 galaxies (BLS1's), we have compiled the emission-line ratios of 36 NLS1's and 83 BLS1's from the literature. We find that the ionization degree and the gas temperature are statistically indistinguishable between NLS1's and BLS1's and thus our results are not inconsistent with the difference of the SED between them.

20. *LRG J0239-0134: A Ring Galaxy or a Pair of Superbubbles at z=1?* (Y. Taniguchi, & T. Murayama)

The unusual morphology of LRG J0239-0134 at z=1.062 has been interpreted as a ring galaxy. However, we propose an alternative idea that the ringlike morphology is attributed to a pair of superbubbles driven by the intense starburst in the central region of this galaxy. We suggests that this galaxy provides an important example of the superwind activity at high redshift.

21. *A New Interpretation of Chain Galaxies at High Redshift* (Y. Taniguchi, & Y. Shioya)

We propose a possible new model for the formation of chain galaxies at high redshift. We also discuss that shocked shells driven by superwinds may be responsible for some Lyman limit systems and damped Lyα systems because their H I column densities are expected to be $N_{\rm HI} > 10^{19}$ cm^{-2}.

22. *SIO Emission in the Multilobe Outflow Associated with IRAS 16293-2422* (N. Hirano, H. Mikami, T. Umemoto, S. Yamamoto, & Y. Taniguchi)

We have mapped the thermal emission line of SiO (v=0; J=2-1) associated with the quadrupolar molecular outflow driven by the very cold far-infrared source IRAS 16293-2422. 16293-2422. The SiO emission is significantly enhanced in the northeastern red lobe and at the position 50" east of the IRAS source. Strong SiO emission observed at 50" east of the IRAS source presents evidence for a dynamical interaction between a part of the eastern blue lobe and the dense ambient gas condensation.

23. *On the Hidden Nuclear Starburst in Arp 220* (Y. Shioya, N. Trentham, & Y. Taniguchi)

We construct a starburst model for the hidden starbursts in Arp 220. Comparing these stellar population synthesis models with observations, we show that the hidden power source must be due to star formation (as opposed to an active galactic nucleus) at the 50in order to avoid an ionizing photon excess problem and this starburst must be young ($< 7 \times 10^7$ yr). We derive a current star formation rate of 270 $M_\odot$ yr^{-1} and an extinction $A_V > 30$ mag for our line of sight to this hidden starburst.

24. *Photometric properties of the Arp 220 super star clusters* (Y. Shioya, Y. Taniguchi, & N. Trentham)

We investigate the photometric properties of six super stellar clusters (SSCs) seen in both the optical and near-infrared Hubble Space Telescope images of the local ultraluminous starburst galaxy Arp 220. Comparing the observed spectral energy distributions (SEDs) of the SSCs with the Starburst99 models we confirm that all three nuclear SSCs are heavily obscured ($A_V \sim$ 10mag). On the other hand, the circumnuclear SSCs have little internal extinction ($A_V \leq$ 1mag).

25. *Where is the[O III] λ4363 Emitting Region in Active Galactic Nuclei?* (T. Nagao, T. Murayama, & Y. Taniguchi)

We report on several pieces of evidence that a large fraction of the [O III] λ4363 emission arises from the dense gas obscured by putative tori. It is shown that the observed higher values of [O III] of type 1 AGNs may be explained by introducing a 5%-20% contribution from the dense component, while those of type 2 AGNs may be explained by introducing a 0%-2% contribution.

26. *1. CO Observations of Luminous IR Galaxies at Intermediate Redshift* (Tutui, Y., Sofue, Y., Honma, M., Ichikawa, T., and Wakamatsu, K.)

We present new measurements of the 12CO (J=1-0) emission from 16 luminous infrared galaxies (LIGs) at intermediate redshift ($cz \sim 10000-50000$ km s^{-1}). These new data were selected by isolated and normal morphology. Although there already exist measurements of CO emission from LIGs in the literature, they are mostly strongly interacting/merging systems.

Publications

1. Discovery of a Low Surface Brightness Object near Seyfert's Sexte, T. Murayama, S. Nishiura, T. Nagao, Y. Sato, Y. Taniguchi, D.B. Sanders, 2000, AJ, **119**. 1691-1694

2. Detection of the VLBI-Scale Counter Jet in NGC 6251, H. Sudou, Y. Taniguchi, Y. Ohyama, S. Kameno, S. Sawada-Satoh, M. Inoue, O. Kaburaki, & T. Sasao, 2000, Astrophysical Phenomena Revealed by Space VLBI, Proceedings of the VSOP Symposium, Eds.: H. Hirabayashi, P.G. Edwards, and D.W. Murph (ISAS), 75-78

3. Grain Survival in Supernova Remnants and Herbig-Haro Object, H. Mouri, & Y. Taniguchi, 2000, ApJ, **534**, L63-L66

4. High-Ionization Nuclear Emission-Line Region of Seyfert Galaxies, T. Nagao, Y. Taniguchi, & T. Murayama, 2000, AJ, **119**, 2605-2628

5. The Nuclear Activity of Galaxies in the Hickson Compact Groups, M. Shimada, Y. Ohyama, S. Nishiura, T. Murayama, & Y. Taniguchi, 2000, AJ, **119**, 2664-2685

6. Formation of Intermediate-Mass Black Holes in Circumnuclear Regions of Galaxies, Y. Taniguchi, Y. Shioya, T. G. Tsuru, & S. Ikeuchi, 2000 PASJ, **52**, 533-537

7. Luminous Infrared Galaxies. III. Multiple Merger, Extended Massive Star Formation, Galactic Wind, and Nuclear Inflow in NGC 3256, S.Lipari, R. Diaz, Y. Taniguchi, R. Terlevich, H. Dottori, G. Carranza, 2000, AJ, **120**, 645-669

8. Large-Scale Regular Morphological Patterns in the Radio Jet of NGC 6251, H. Sudou, & Y. Taniguchi, 2000, AJ, **120**, 697-702

9. ISO deep far-infrared survey in the "Lockman Hole". II. Power spectrum analysis: evidence of a strong evolution in number counts, H. Matsuhara, K. Kawara, Y. Sato, Y. Taniguchi, H. Okuda, T. Matsumoto, Y. Sofue, K. Wakamatsu, L. L.Cowie, R. D. Joseph, & D. B. Sanders, 2000, A&A, **361**, 407-414

10. Poststarburst Models of LINERS, Y. Taniguchi, Y. Shioya, & T. Murayama, 2000, AJ, **120**, 1265-1272

11. How do we see the nuclear region ($r < 0.1$ pc) of narrow-line Seyfert 1 galaxies?, T. Murayama, T. Nagao, & Y. Taniguchi, 2000, NewAR, **44**, 447-449

12. A Dynamical Study of Galaxies in the Hickson Compact Groups, S. Nishiura, M. Shimada, Y. Ohyama, T. Murayama, & Y. Taniguchi, AJ, **120**, 1691-1712

13. X-Ray Emission from Seyfert 2 Galaxies with Optical Polarized Broad Lines, H. Awaki, S. Ueno, K. A. Weaver, & Y. Taniguchi, 2000, ApJ, **542**, 175-185

14. Deep Optical Imaging of a Compact Group of Galaxies: Seyfert's Sextet, S. Nishiura, T. Murayama, M. Shimada, Y. Sato, T. Nagao, K. Molikawa, Y. Taniguchi, & D. B. Sanders, 2000, AJ, **120**, 2355-2362

15. Dwarf Galaxy Formation Induced by Galaxy Interactions, T. Okazaki, & Y. Taniguchi, 2000, ApJ, **543**, 149-152

16. Numerous Old Starburst Galaxies in the Local Universe, H. Mouri, & Y. Taniguchi, ApJ, **545**, L103-L106

17. Sub-Parsec-Scale Acceleration of the Radio Jet in the Powerful Radio Galaxy NGC 6251, H. Sudou, Y. Taniguchi, Y. Ohyama, S. Kameno, S. Sawada-Satoh, M. Inoue, O. Kaburaki, & T. Sasao, 2000, PASJ, **52**, 989-995

18. ISO continuum observations of quasars at z=1-4. I. Spectral energy distributions of quasars from the UV to far-infrared, S. Oyabu, K. Kawara, Y. Tsuzuki, Y. Sofue, Y. Sato, H. Okuda, Y. Taniguchi, H. Shibai, C. Gabriel, T. Hasegawa, & E. Nishihara, 2000, A&A, **365**, 409-416

19. The Narrow-Line Region of Seyfert Galaxies: Narrow-Line Seyfert 1 Galaxies versus Broad-Line Seyfert 1 Galaxies, T. Nagao, T. Murayama, & Y. Taniguchi, 2000, ApJ, **546**, 744-758

20. LRG J0239-0134: A Ring Galaxy or a Pair of Superbubbles at z=1?, Y. Taniguchi, & T. Murayama, 2000, ApJ, **547**, L13-L16

21. A New Interpretation of Chain Galaxies at High Redshift, Y. Taniguchi, & Y. Shioya, 2000, ApJ, **547**, 146-153

22. SIO Emission in the Multilobe Outflow Associated with IRAS 16293-2422, N. Hirano, H. Mikami, T. Umemoto, S. Yamamoto, & Y. Taniguchi, 2000, ApJ, **547**, 899-906

23. On the Hidden Nuclear Starburst in Arp 220, Y. Shioya, N. Trentham, & Y. Taniguchi, 2000, ApJ, **548**, L29-L32

24. Photometric properties of the Arp 220 super star clusters, Y. Shioya, Y. Taniguchi, & N. Trentham, 2000, MNRAS, **321**, 11-17

25. Where is the[O III] λ4363 Emitting Region in Active Galactic Nuclei?, T. Nagao, T. Murayama, & Y. Taniguchi, 2000, ApJ, **549**, 155-171

26. CO Observations of Luminous IR Galaxies at Intermediate Redshift, 2000, Publ. Astron. Soc. Japan, Tutui, Y., Sofue, Y., Honma, M., Ichikawa, T., and Wakamatsu, K.

(VI) Cluster of galaxies and large scale structures

1. *A possible route to spontaneous reduction of the heat conductivity by a temperature gradient driven instability in electron-ion plasmas*, (Makoto Hattori, Keiichi Umetsu)

A possible route to spontaneous reduction of the heat conductivity by a temperature gradient driven instability in electron-ion plasmas is shown by linear perturbation theory based on plasma kinetic theory.

2. *Emission-line properties of MG 2016+112: A luminous obscured quasar at high redshift* (T.Yamada, S.Yamazaki, M.Hattori, G.Soucail, J.-P.Kneib)

Emission-line properties of the QSO MG 2016+112 is shown observationally.

3. *Spectroscopic confirmation of a cluster of galaxies at z=1 in the field of the gravitational lens MG2016+112* (G.Soucail, J.-P.Kneib, A.O.Jaunsen, J.Hjorth, M.Hattori, T.Yamada)

Existence of the clusters of galaxies at $z = 1$ in the MG2016 field is confirmed by spectroscopical observations of the possible member galaxies.

4. *Substructures Revealed by the Sunyaev-Zel'dovich Effect at 150 GHz in a High-Resolution Map of RX J1347-1145* (E.Komatsu, H.Matsuo, T.Kitayama, M.Hattori, R.Kawabe, K.Kohno, N.Nario, S.Schindler, Y.Suto, K.Yoshikawa)

Existence of the massive substructures in the distant cluster RXJ1347-1145 is shown by mm-wave band observations.

Publications

1. A possible route to spontaneous reduction of the heat conductivity by a temperature gradient driven instability in electron-ion plasmas, Makoto Hattori, Keiichi Umetsu, Astrophysical Journal **533**, 84-94, (2000)

2. Emission-line properties of MG 2016+112: A luminous obscured quasar at high redshift, T.Yamada, S.Yamazaki, M.Hattori, G.Soucail, J.-P.Kneib, Astronomy & Astrophysics **367**, 51-58, (2001)

3. Spectroscopic confirmation of a cluster of galaxies at z=1 in the field of the gravitational lens MG2016+112, G.Soucail, J.-P.Kneib, A.O.Jaunsen, J.Hjorth, M.Hattori, T.Yamada, Astronomy & Astrophysics **367**, 741-747, (2001)

4. Substructures Revealed by the Sunyaev-Zel'dovich Effect at 150 GHz in a High-Resolution Map of RX J1347-1145, E.Komatsu, H.Matsuo, T.Kitayama, M.Hattori, R.Kawabe, K.Kohno, N.Nario, S.Schindler, Y.Suto, K.Yoshikawa, Publications of Astronomical Society of Japan **53**, 57-62, (2001)

(VII) Cosmology: Theory and Observation

1. 「Determination of the Hubble Parameter with the Gravitational Lens S ystem PG1115+080」、M. Tada and T. Futamase、Progress of Theoretical Physics, 104, 971-9 80, (2000)

We examine the lens model with the quadruple gravitational lens syst em PG115+080 to estimate the HUbble constant, paying particular attention to the dep endence on the density profile. We found that a wide range of th e values of the Hubble constant is statistically acceptable for a reasonable range of the power law index of the density distribution.

2. 「Effects of Weak Lensing on the Topology of CMB Maps」 J. Schmelzing, M. Takada and T. Futamase、Astrophysical Journal letters, 544, L83-L86, (2000)

We propose to use Minkowski functional to investigate non-Gaussan pr operties generated by gravitational lensing of large scale struc ture in the isotemperature map of cosmic macrowave background radiation.

3. 「Detectability of Gravitational Lensing Effects on the Two-Point Corr elation Function of Hotspots in the CMB Maps」、 M. Takada and T. Fut amase、Astrophysical Journal, 546, 620-634, (2000)

We studied the gravitational lensing effects on the two-point correla tion function of hot spots in the cosmic macrowave background radiation. We found that the effec ts are detectable in the future experiment and give us information of the large scale s tructure formation.

4. 「Detection of Dark Matter Concentrations in the Field of Cl 1604+430 4 from Weak Lensing Analysis」、K. Umetsu and T. Futamase、Astrophysical Journal Letters , 539, L5-L9, (2000)

We present a weak lensing analysis of a region around the galaxy clus ter Cl1604+4304 on the basis of the deep observations with the HST/WFPC2. We found the dark mass concentration which is not optically identified.

5. 「A new measure of sigma8 using the lensing dispersion in high z type Ia Sne」、T. Hamana and T. Futamase、Astrophysical Journal, 534, 29-33, (2000)

We studied a scatter in the peak magnitutdes of high-redshift Type I a supernovae (SN Ia) induced by the gravitational lensing magnification due to large-scal e structures. It is found that the number and quality of SN Ia data needed for pla cing a useful constraint on the structure formation scinario is attai nable with the Next Generation Space Telescope.

6. 「Equation of Motion for Relativistic Compact Binaries with Strong Field Point Particle Limit: Formulation, the first post-Newto nian and multipole terms], Y. Itoh, T. Futamase and H. Asada、Physical eview D62, 064002, (2000)

General relativistic equation of motion for relativistic compact binar ies such as neutron stars or black holes is studied. The method of poi nt particle limit with strong internal gravity is used to avoid variou s ambiguities appeared in other approach.

7. 「Gravitational Lensing Effect on the Correlation of Hotspots in the Cosmic Microwave Background as the sensitive measure of sigma8」、M. Tak ada, E. Komatsu and T. Futamase、Astrophysical Journal Letters, 533, L83 -L86, (2000)

We studied the weak lensing effect due.to the large scale sytructure of the universe on the two point correlations of local maxima in the 2D sk y map of the cosmic microwave background anisotropy. We found that the lensng fairly smoothes the oscillatory features

of the two point correlation function and the correlation can be a new measure of the power spectrum of matter fluctuations from the lensing signatures.

8. 「Statistics of Weak Gravitational Lensing in Cold Dark Matter Models」:、 T. Hamana, H. Martel and T. Futamase、 Astrophysical Journal, 529, 56-63, (2000)

We compute statistical properties of weak lensing by large scale structu re in three cold Dark Matter models. We show that the magnification bias is moderate in the absence o f the power law tail in the magnification distribution, but depends stro ngly on the value of the density parameter.

9. *Power spectrum of the Sunyaev-Zel'dovich effect* (Alexandre Refregier, Eiichiro Komatsu, David N. Spergel, and Ue-Li Pen)

Using the state-of-the-art hydrodynamic simulations and analytic methods, the authors predict angular powerspectrum of the cosmic microwave background anisotropy through the Sunyaev-Zel'dovich (SZ) effect arising from clusters of galaxies and gas in intergalactic medium. The authors find that both approaches agree with each other, and the predicted SZ anisotropy dominates over the primary signal on small angular scales of, typically, below several arcminutes.

10. *Substructures revealed by the Sunyaev-Zel'dovich effect at 150GHz in a high resolution map of RXJ1347-1145* (Eiichiro Komatsu, Hiroshi Matsuo, Tetsu Kitayama, Makoto Hattori, Ryohei Kawabe, Kotaro Kohno, Nario Kuno, Sabine Schindler, Yasushi Suto, and Kohji Yoshikawa)

With their high-resolution mapping observations, the authors detect complicated morphological structures in the cluster of galaxies at $z = 0.45$ through the Sunyaev-Zel'dovich (SZ) effect. This is the first detection of the substructure in the cluster of galaxies through the SZ effect, and implies that the substructure in clusters should affect measurements of cosmological parameters from SZ observations.

11. *Acoustic signatures in the primary microwave background bispectrum* (Eiichiro Komatsu, and David N. Spergel)

The authors provide theoretical predictions for the three-point correlation function of the cosmic microwave background radiation (CMB) anisotropy. Especially, the primary signal from inflation is investigated in detail. The authors find that the three-point correlation of CMB from inflation is too small to be detected, as long as simple slow-roll inflationary scenarios are right.

12. *The Discovery of a Luminous z=5.80 Quasar from the Sloan Digital Sky Survey* (Fan, X., White, R. L., Davis, M., Becker, R. H., Ichikawa, T., et al.)

We present observations of SDSSp J104433.04-012502.2, a luminous quasar at $z = 5.80$ discovered from Sloan Digital Sky Survey (SDSS) multicolor imaging data. This object was selected as an i'-band dropout object, with $i^* = 21.8 \pm 0.2$ and $z^* = 19.2 \pm 0.1$.*Ithasanabsolutemagnitude*$M_{1450} = -27.2$ ($H_0 = 50$ km s$^{-1}Mpc^{-1}$, $q_0 = 0.5$). The spectrum shows a strong and broad Lyα; emission line, strong Lyα.

Publications

9. Power spectrum of the Sunyaev-Zel'dovich effect, Alexandre Refregier, Eiichiro Komatsu, David N. Spergel, and Ue-Li Pen, Physical Review D **61**, 123001 1-11 (2000).

10. Substructures revealed by the Sunyaev-Zel'dovich effect at 150GHz in a high resolution map of RXJ1347-1145, Eiichiro Komatsu, Hiroshi Matsuo, Tetsu Kitayama, Makoto Hattori, Ryohei Kawabe, Kotaro Kohno, Nario Kuno, Sabine Schindler, Yasushi Suto, and Kohji Yoshikawa, Publications of the Astronomical Society of Japan, 53, 57-62 (2001).

11. Acoustic signatures in the primary microwave background bispectrum, Eiichiro Komatsu, and David N. Spergel, Physical Review D 63, 063002, 1-13 (2001).

12. The Discovery of a Luminous z=5.80 Quasar from the Sloan Digital Sky Survey, 2000, Astron. J., **120**, 1167–1174, Fan, X., White, R. L., Davis, M., Becker, R. H., Ichikawa, T., et al.

(VIII) Instrumentation

1. *Narrowband filter system at the Subaru prime focus* (T. Hayashino, Y. Taniguchi, T. Yamada, Y. Shioya, T. Nagao, T. Yoshidam M. Doi, K. Shimasaku, Y. Komiyama, F. Nakata, H. Furusawa, H. Kimura, M. Ouchi, T. Aoki, M. Hamabe, K. Kodaira, S. Miyazaki, N. takato, M. Yagi, N. Yasuda, M. Sekiguchi, & S. Okamura)

The Subaru telescope has an excellent performance of wide field of view at the prime focus. A big area of 30 feet times 24 feet is observable at a time with the prime focus camera. Making the best use of the wide view, we are constructing narrowband (NB) filter system consisting of 20 bands. This system covers the wavelengths between 4,000 Å and 10,000 Å. The band width (BW) varies form 200 Å to 400 Å depending on the center wavelength (CW). The resolving power of the system is 23.

2. *The Application of MP-FTS to Aperture Synthesis* (M.Hattori, I.S.Ohta, H.Matsuol Y.Shibata)

An original aperture synthesis system is proposed theoretically.

3. *The Sloan Digital Sky Survey: Technical Summary* (York, D. G., Adelnam, J., Anderson, E., Scott, S. F., Ichikawa, T., et al.)

The Sloan Digital Sky Survey (SDSS) will provide the data to support detailed investigations of the distribution of luminous and nonluminous matter in the universe: a photometrically and astrometrically calibrated digital imaging survey of π sr above about Galactic latitude 30° in five broad optical bands to a depth of $g' \sim 23$ mag, and a spectroscopic survey of the approximately 106 brightest galaxies and 105 brightest quasars.

Publications

1. Narrowband filter system at the Subaru prime focus,

T. Hayashino, Y. Taniguchi, T. Yamada, Y. Shioya, T. Nagao, T. Yoshidam M. Doi, K. Shimasaku, Y. Komiyama, F. Nakata, H. Furusawa, H. Kimura, M. Ouchi, T. Aoki, M. Hamabe, K. Kodaira, S. Miyazaki, N. takato, M. Yagi, N. Yasuda, M. Sekiguchi, & S. Okamura, 2000, SPIE, **4008**, 397-404

2. The Application of MP-FTS to Aperture Synthesis, M.Hattori, I.S.Ohta, H.Matsuol Y.Shibata, ISAS Report SP **14**, 352-360, (2000)

3. The Sloan Digital Sky Survey: Technical Summary, 2000, Astron. J., **120**, 1579–1587, York, D. G., Adelnam, J., Anderson, E., Scott, S. F., Ichikawa, T., et al.

Doctor Theses

D1) Daisuke Kawata: A Numerical Study of the Formation of Elliptical Galaxies .
D2) Kohji Morikawa:A Statistical study of galaxy images lensed by galaxy clusters.
D3) Yoshiyuki Sakurai: Optically thick winds in the decay phase of novae.
D4) Yoshihiro Takada: Gravitational Lensing Effect of Large-scale Structure on Cosmic Microwave Background.
D5) Keiichi Umezu: A Weak Lensing Study of Galaxy Clusters.

Master Theses

M1) Masashi Aoyagi: Dynamical interactions between a galactic bulge and a bar.
M2) Seiichiro Ariyoshi: Development of a submilimeter camera for ASTE(Atacama Submillimater Telescope Experiment).
M3) Izumi Ohota: Application of Marint and Puplett Fourier spectrograph to aparture synthesis astronomical interferometr.
M4) Masaaki Ohtuka: Spectropcopic analyses of planetary nebulae in the galactic halo.
M5) Takashi Suzuki: Numerical simulation of dwarf galaxies.
M6) Ryuji Suzuki: A design of a muluti objects near infrared spectrograph.
M7) Chihiro Tokoku: Development of an interchangeable colled multi-slit for a near inrared multi objects spectrograh.
M8) Toru Nagao: New aspects on ionized gas clouds in narrow-line regions of Seyfert galaxies.